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MISCELLANEOUS

Use of a single bipolar electrode in the posterior arytenoid muscles for bilateral monitoring of the recurrent laryngeal nerves in thyroid surgery

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Abstract The aims were to assess the technical feasibility of using a single electrode in the posterior arytenoid muscles (PAM) for intraoperative monitoring of the recurrent laryngeal nerve (RLN) in thyroid surgery, to validate the new method against the insertion of electrodes placed in the vocal cord muscle, and to report the results of the clinical application of the new concept. A total of 52 patients were enrolled. The handling and safety of RLN monitoring was tested by simultaneous registration of the EMG response from vocal fold electrodes and PAM electrodes. Acoustically and electromyographically we found nearly the same values for the arytenoid muscles as for the vocal folds, although the signals taken from the vocal folds were slightly stronger. PAM recording using a single bipolar electrode is technically feasible and as reliable compared to the standard vocal cord monitoring.

Keywords Recurrent laryngeal nerve · Micro direct laryngoscopy · Vocal cord muscle · Posterior arytenoid muscles · Hook-wire electrode · Electromyographic baseline

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We declare that we have no conflict of interest.

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Introduction

The standard of care during routine parotidectomy, temporal bone and lateral skull base surgery is the preservation of the seventh cranial nerve, which was first described by Thomas Carwardine in 1907 [1]. In analogy to facial nerve monitoring, intraoperative monitoring of the recurrent laryngeal nerve (RLN) has been promoted during the past two decades [1–6]. Several methods of monitoring vocal cord movements intraoperatively have been described. Frequently used are needle electrodes inserted into the vocal muscles either by direct laryngoscopy prior to the operation or through the cricoid membrane and monitoring their movements [7]. Alternatively double-balloon endotracheal tubes [8, 9] recording pressure changes or conductive silver electrodes attached to the endotracheal tube may be used. The optical registration by direct laryngoscopy during the operation is a very exact method but requires too much of technology and manpower. The “exact laryngeal twitch” by manual palpation is also a safe way to observe the function of the RLN. Our ENT department favour hook-wire electrodes placed into the vocal folds by direct laryngoscopy prior to the surgery. In the last 10 years, we have gained good experience with this method in over 1,700 thyroid or parathyroid surgeries. However, in approximately 5% of patients the anatomical situation of the endolarynx is difficult to expose by direct laryngoscopy limiting an exact placement of the electrodes. The purpose of this report is to present a new technique of monitoring the RLN with the use of a single paired electrode placed in the posterior arytenoid muscles (PAM). The monitoring device was an Avalanche©-EMG monitor with continuous audio and visual monitoring of the integrity of the motor nerve during surgery.

Materials and methods

The data were collected prospectively and all consecutive patients undergoing partial or total thyroidectomy from September 2004 to February 2005 were considered candidates for the study. The study was designed to determine the acoustical and electromyographical properties by simultaneous monitoring the vocal cord muscle (VCM) and the PAM, using continuous intraoperative nerve recordings on the 8-channel Avalanche©-EMG monitor. Fifty-two patients underwent hemi- or total thyroidectomy at the ENT-Department within the 6 months study period. Total thyroidectomy was performed in 11 cases, 23 patients underwent a hemithyroidectomy on the right side, while 18 patients underwent a hemithyroidectomy on the left side. After induction of general anaesthesia direct laryngoscopy was performed using Kleinsasser instruments. Bipolar needle electrodes were inserted into both vocalis muscles (VCM) as well as into the PAM. It is worth mentioning that even in total thyroidectomy only one paired needle electrode had to be inserted into the muscles between the arytenoids (PAM) to monitor bilateral function of the RLM (Fig. 1). All electrodes—including the ground electrode—were connected to the 8-channel Avalanche©-monitor. Simultaneous tracings from the VCM and PAM were always obtained. The stimulating current threshold was set at 2 mA and the RLN was always identified surgically, visualized and stimulated at its crossing with the inferior thyroid artery. A special software program was developed by the Dr. Langer Medical GmbH company enabling the exact evaluation of the signals. The following parameters were compared with each other: the acoustic signal, the electromyographic baseline (EMB) at the beginning of the operation and immediately before the first stimulation, the amplitude and the latency time.

For statistical analyses the Kolmogorov–Smirnov-Adaptation test was used to examine normal distribution and the *f*-test to compare variations. The Wilcoxon–Rank-Sum test was chosen for verification. A P value of less than 0.05 was considered to be statistically significant.

Results

Overall 156 valuable EMG responses were recorded in 63 surgical cases (29 on the left, 34 on the right side) from the vocal cords (VCM) and from the PAM. A distinct audible signal was obtained in 62 cases (98.4%) of the VCM group and in 61 cases (96.8%) of the PAM group. There was no significant difference ($P > 0.05$) between the two groups. In three patients a characteristic signal was not audible although EMG recordings were visible on the monitor screen. No injuries to the RLN were observed intra- or postoperatively.

The EMB at beginning of the operation (Fig. 2) was higher in the VCM-group (36.52 ± 18.72 mV) compared to the PAM-group (25.02 ± 12.34 mV). The difference of 11.50 mV between the two muscle groups was highly significant ($P < 0{,}001$). Contrary to these initial measurements there was no significant difference between the two muscle groups comparing the intraoperative EMB immediately before the first stimulation. In the VCM-group the potential reached on average 20.02 mV (±9.74 mV), whereas in the PAM-group it was recorded at 18.49 mV (±7.47 mV). The difference between the EMB at the beginning of the operation and immediately before the first stimulation (delta EMB) was on average 16.49 mV (±20.96 mV) in the VCM-group and 6.53 mV (±13.82 mV) in the PAM-group ($P < 0.05$).

The amplitude in the VCM-group was recorded at 5.07 mV (±2.21 mV). In the PAM-group, the amplitude was significantly lower with an average of 1.78 mV (±1.07 mV). The difference of 3.26 mV was statistically

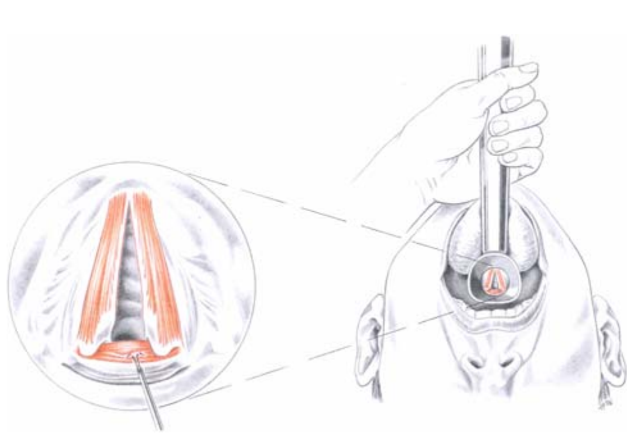

Fig. 1 Under direct laryngoscopy view, one paired needle electrode is inserted into the arytenoid muscles

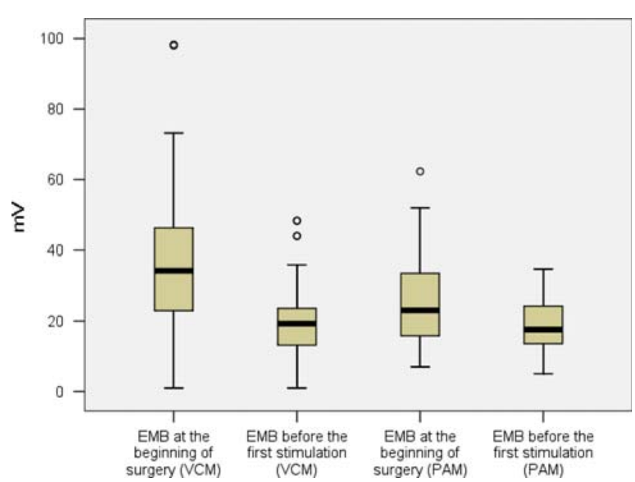

Fig. 2 Electromyographic baseline (*EMB*) at the beginning of surgery

highly significant ($P < 0.001$). The results of the amplitudes are shown in Fig. 3.

The latency time (Fig. 4) was virtually identical with 3.05 ms (±0.29 ms) for the VCM-group, and for the PAM-group, where the latency time is on average 3.01 ms (±0.24 ms). The difference of 0.04 ms was statistically not significant ($P > 0.1$).

Discussion

Nerve monitoring during surgery does not substitute the anatomical knowledge of the surgeon, but it may help to localize the nerve fibres in revision cases, large tumor masses and infiltrating lesions and it confirms the functional integrity of the nerve upon stimulation. Monitoring of the RLN has become a routine practise in most centres performing thyroid and parathyroid surgeries as well as in centres performing lateral skull base surgeries, where the vagal nerve may be at risk. There are several choices for RLN monitoring, reviewed in detail by D. W. Eisele in1996 [5].

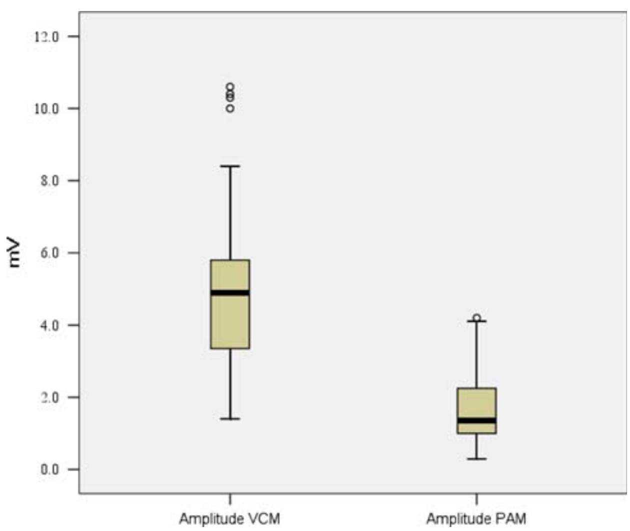

Fig. 3 The amplitudes of vocal cord muscle (VCM) and posterior arytenoid muscles (PAM)

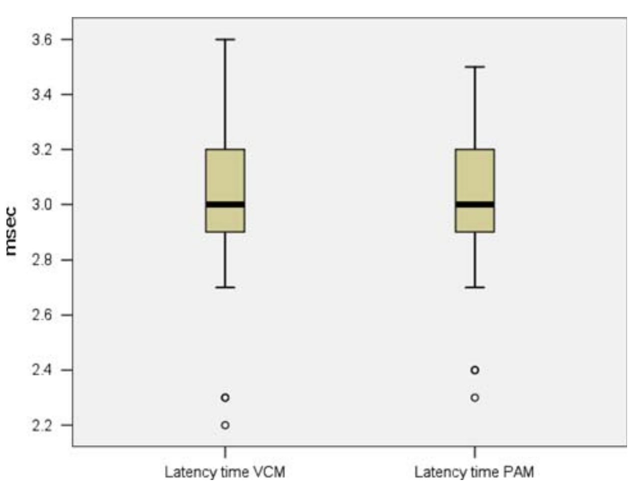

Fig. 4 The latency time of VCM and PAM

Rice and Cone-Wesson reported their early experience using hook-wire electrodes and evoked EMG recordings to verify the nerve integrity during the surgery and to reduce the risk of injury [10]. Endotracheal tube electrodes were initially investigated by Woltering et al. in 1984 using a small group of 12 patients [9]. Eisele [5] reported his positive experience 12 years later with a cohort of 31 patients and Mermelstein et al. [11] verified a stable and continuous recording with the electrodes attached to the endotracheal tube in 28 patients. Neither Eisele nor Mermelstein reported any complications. Mermelstein evaluated an electrode attachment to the endotracheal tube that provides a more reliable device than the commercially available wired endotracheal tubes at that time. Problems of temporary failures were noted from time to time using the commercially available wired endotracheal tubes, therefore, she used a modified device to provide a constant contact with the surface of the larynx across the vocal folds.

A double-balloon endotracheal tube was presented by Lamade et al. [12] as an “all in one” device, enabling continuous transtracheal stimulation and recording of the RLN and allowing direct stimulation of the nerve using standard stimulation probes. In two out of their 55 patients difficulties were encountered during the operation (disturbed audible signal) with one persistent RLN lesion.

Rotation of the endotracheal tube during intubation or following head positioning on the operating table may occur, as well as intraoperative tube obstruction due to kinking of the more flexible tube. Another drawback is the cost of these endotracheal devices (up to $175). Whereas most visceral surgeons, unfamiliar with the endolaryngeal anatomy, favour endotracheal tube electrodes, many otolaryngologists rely on direct laryngoscopy and insertion of needle electrodes into the vocal muscles.

In anatomically difficult situations, visualization of the vocal folds may not be possible. Marcus et al. described in the University of Michigan Experience the use of a postcricoid surface electrode [13]. Their initial report established normative data and confirmed its simplicity. However, it mandates a separate storage of this paddle-style electrode and—to our knowledge—the company (Medtronic Xomed Surgical Products, Inc., Jacksonville, FL, USA) discontinued the production of this model. In the unexpected situation of impaired visualization of the vocal cords, we established an alternative way to place the same electrodes for continuous monitoring. Our study confirmed the value of inserting a single paired electrode into the PAM group.

While the initial EMB and the maximum amplitudes were different between the vocal and PAM, the latency was almost identical due to the close anatomical relationship of these muscles and the RLN pathway. According to Faaborg-Andersen [14], "the intensity of muscle contraction is graded not only by the discharge frequency of the single motor unit but also by the number of innervated motor units, as well as the number of active fibres innervating the motor units". The strength of contraction can be inferred from the action potential recording: the mean amplitude of the integrated action potentials is directly proportional with the strength of contraction. Therefore, our different findings between the two muscle groups regarding the EMB at the beginning of the surgery, and the maximum amplitudes are due to the different number of innervated motor units and the different number of muscle fibres per motor unit. Despite the lower muscle mass of the vocal muscle compaired to the PAMs, the VCM group features the higher number of innervated motor units, and the more muscle fibres per motor unit resulting in a higher initial EMB and maximum amplitudes.

Most surgeons do not visualize the EMG curves but rely on the acoustical signal properties upon stimulation, while dissecting along the nerve fibres or during nerve stimulation. There was no significant difference between the two modes of electrode placements. In three patients, the acoustical signal was not sufficiently detectable although the actual EMG recordings were not impaired. A technical defect of the audio output could be excluded, leaving the true nature of this malfunctioning unclear. However, it did not have any impact on the outcome of the surgeries.

In the hands of an experienced surgeon used to place electrodes into vocal cords, the placement is straight forward and there is no necessity to switch to other monitoring strategies. As the price of a paired electrode is approximately a tenth of an endotracheal tube setting, the costs effectiveness is favourable for the needle electrodes.

We continue to routinely monitor the function of the RLN using hook-wire electrodes placed into the vocal muscles. In patients with a short neck, difficult head positioning due to lesions of the vertebral column (e.g. M. Bechterev, previous spine surgery, compression syndromes of the vertebral column) or distorted laryngeal visualization there is now another option for the electrode placement: monitoring the PAMs with a single paired electrode is technically simple and allows simultaneous recordings of both RLNs even in total thyroidectomy or bilateral exploration of the parathyroid glands.

Conclusion

We describe a new method for intraoperative monitoring of the RLN in thyroid or parathyroid surgery where the vocal cords are visually impaired: a single bipolar electrode placed in the PAMs. This method seems to be simple, safe, and effective, especially in difficult laryngeal anatomy, and it works as reliable compared to the standard vocal cord monitoring.

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